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ATTENUATION OF Ka-BAND ENERGY BY SNOW AND ICE

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FOREWORD

The study described in this report is part of a continuing effort to obtain data that will be valuable for radiometer mapping at millimeter frequencies. The work was funded by WEPTASK R360-FR-104/211-1/R011-01-01 and AIR 360-016/211-1/S061.

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ABSTRACT

Measurements of the attenuation of electromagnetic energy by snow and the reflection of radiation from snow and ice were made by using an interferometer and manufactured snow and ice in an environmental chamber under closely controlled conditions. The ambient temperature was held at -14°F for all measurements. Snow and ice attenuation and reflection measurements are tabulated for various snow densities covering the range from 32 to 39 GHz. Results show that packed snow and greater density produce less attenuation.

CONTENTS

INTRODUCTION

The measurements described herein are a continuation of the work reported in Reference 1. The earlier report describes how the transmission and reflection properties of snow are affected by a change in temperature. It was the object of the study described in this report to determine how these same properties are affected by the variation of the snow density at a fixed temperature. The results of these measurements can be used in evaluating the effects of snow or ice coverings on radar backscatter or radiometer measurements.

DESCRIPTION OF APPARATUS

The design of the interferometer used to obtain the measurements is based on the one described in References 1 and 2. However, to prevent the cold temperature from affecting the calibration of the attenuators, the system was redesigned so that the standing-wave detector, the phase shifter, and the attenuators were outside the Tenney walk-in cold chamber. Figure 1 shows the arrangement of the interferometer with respect to the cold chamber.

The radiation from the klystron is divided into two waveguide paths by means of a directional coupler, and the waveguide with the most power is used to transmit the radiation into the chamber. The radiation is then collimated by a horn-lens system and transmitted through the snow sample to a horn and propagated out of the chamber through the waveguide connected to the other branch of the directional coupler. Between the waveguide horn and the directional coupler are an isolator, a hybrid T standing-wave detector, an attenuator, and a phase shifter. The isolator prevents any radiation from the branch of the coupler from entering the chamber; the attenuator matches the amplitude of the radiation coming directly from the klystron with that transmitted through the snow sample; and the phase shifter is used to adjust the phase of the radiation from the klystron so that a null condition can be set up in the detector arm of the hybrid T.

This null condition is set up both with the sample of snow in place and with the snow removed. The difference in readings on the attenuator under the two conditions gives the amount of attenuation loss caused by the snow sample. The reflection loss is measured by replacing the

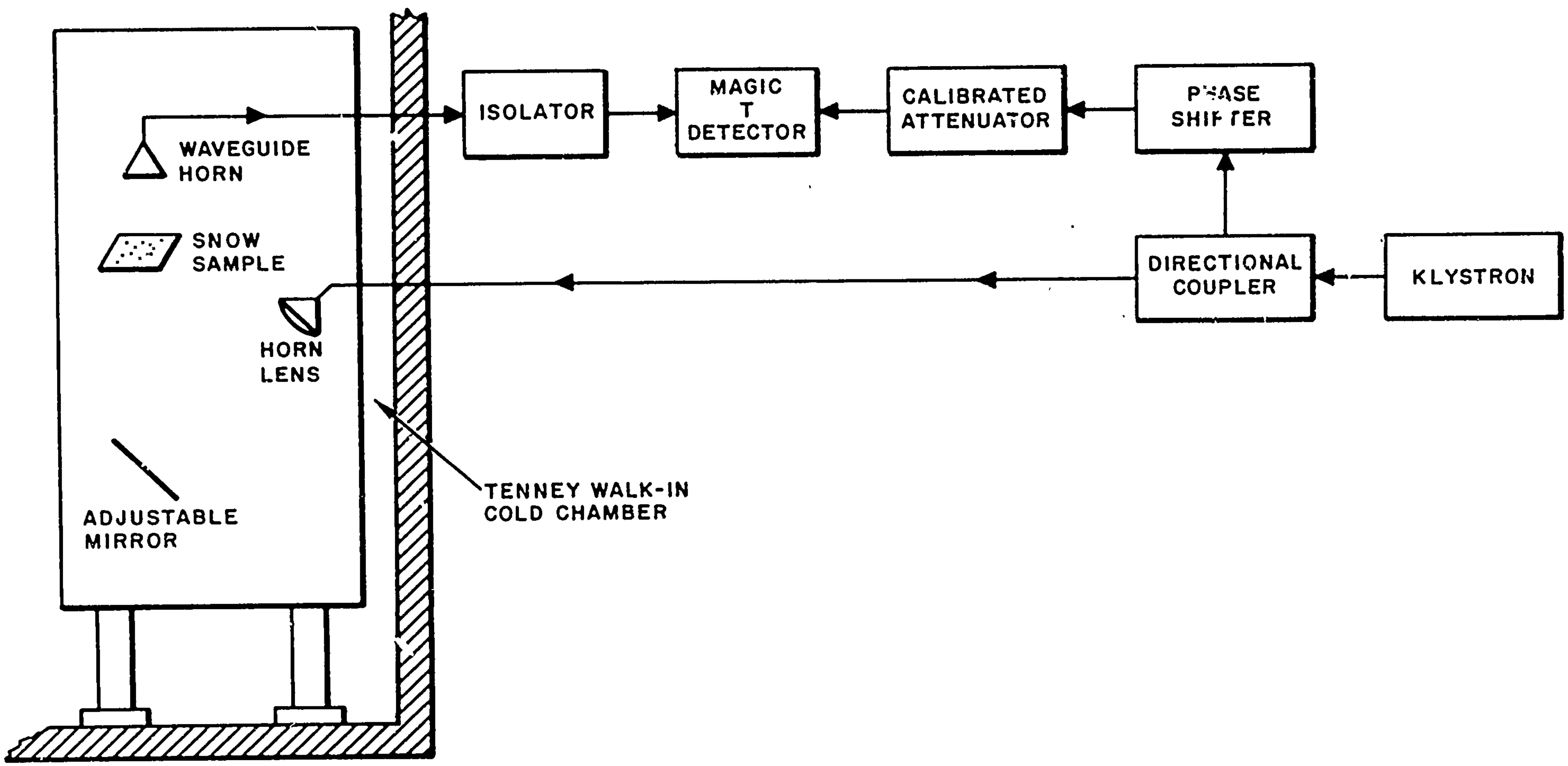

FIGURE 1. Setup for Attenuation Measurements

mirror with a smooth snow sample of an equivalent size. The difference between the attenuator readings with the snow and with the mirror gives the reflection loss.

DESCRIPTION OF SNOW

The snow was made by first cooling the cold chamber to below freezing and then spraying a fine mist of water into it. Figure 2 shows a microphotograph of a sample of the crystals formed on the chamber floor and in the air when the chamber was cooled to about 20° F before being sprayed with cold water. Figures 3-6 are microphotographs of the samples of snow formed when the chamber was cooled to -50° F and sprayed with water. Cold water was used to produce the snow shown in Figure 4, and hot water was used to obtain that shown in Figures 3, 5, and 6. The dimensions of the largest sphere in this group of figures is of the order of a hundredth of an inch, whereas some of the crystals in Figure 2 were as large as one-sixteenth of an inch. It is obvious from these microphotographs that the man-made snow used for the measurements more closely resembles very small hail or sleet than it does natural snow flakes.

RESULTS

All measurements were taken at -14° F. The attenuation measured for the different densities and types of snow are given in Table 1.

TABLE 1. Attenuation Caused by Snow and Ice

Type	Thickness, in.	Density, g/in.^{3}	Loss, dB	Fig. No.
Fine loose snow	5.5	3.35	2.5	3
Fine snow with local packed areas	5.5	5.35	7.2	4
Large ice crystals	5.5	6.42	9.2	2
Packed snow (of type shown in Fig. 3 & 4)	5.5	7.77	1.4	5
Slab of ice[a]	2	15.05	1.2	-

[a]Made from distilled water.

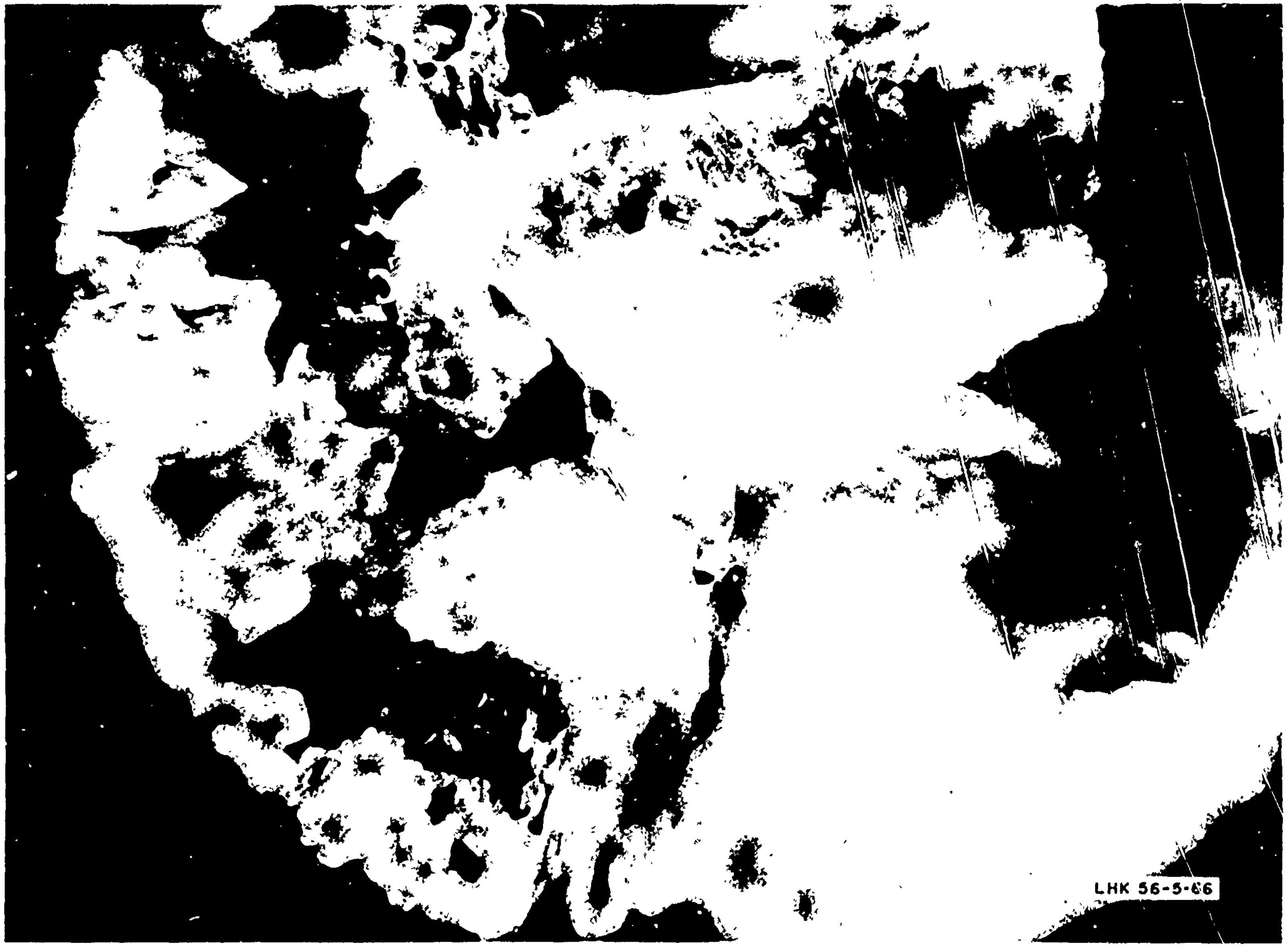

FIGURE 2. Ice Crystals Formed by Spraying Cold Water into 20°F Chamber

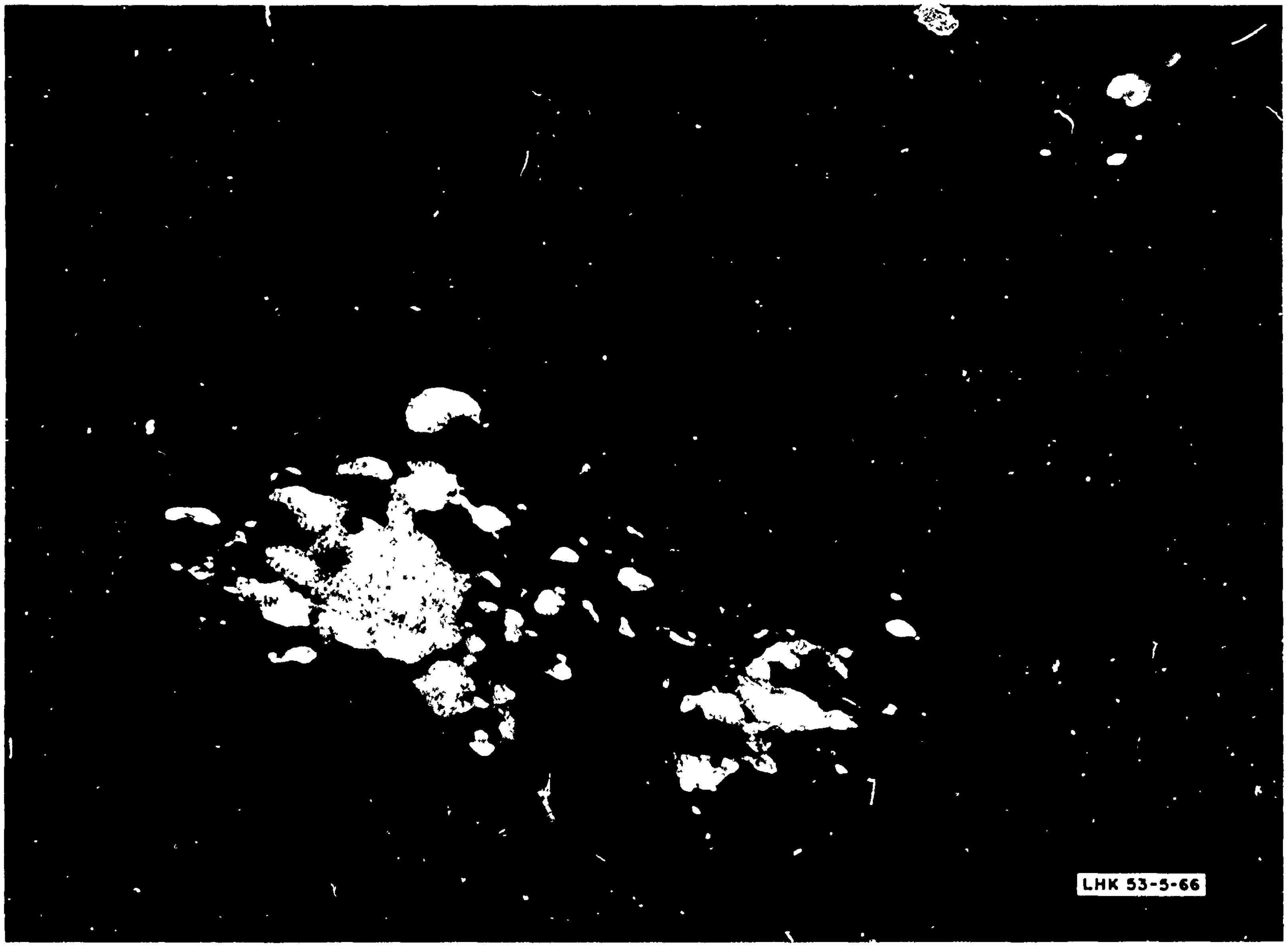

FIGURE 3. Snow Formed by Spraying Hot Water into -50° F Chamber

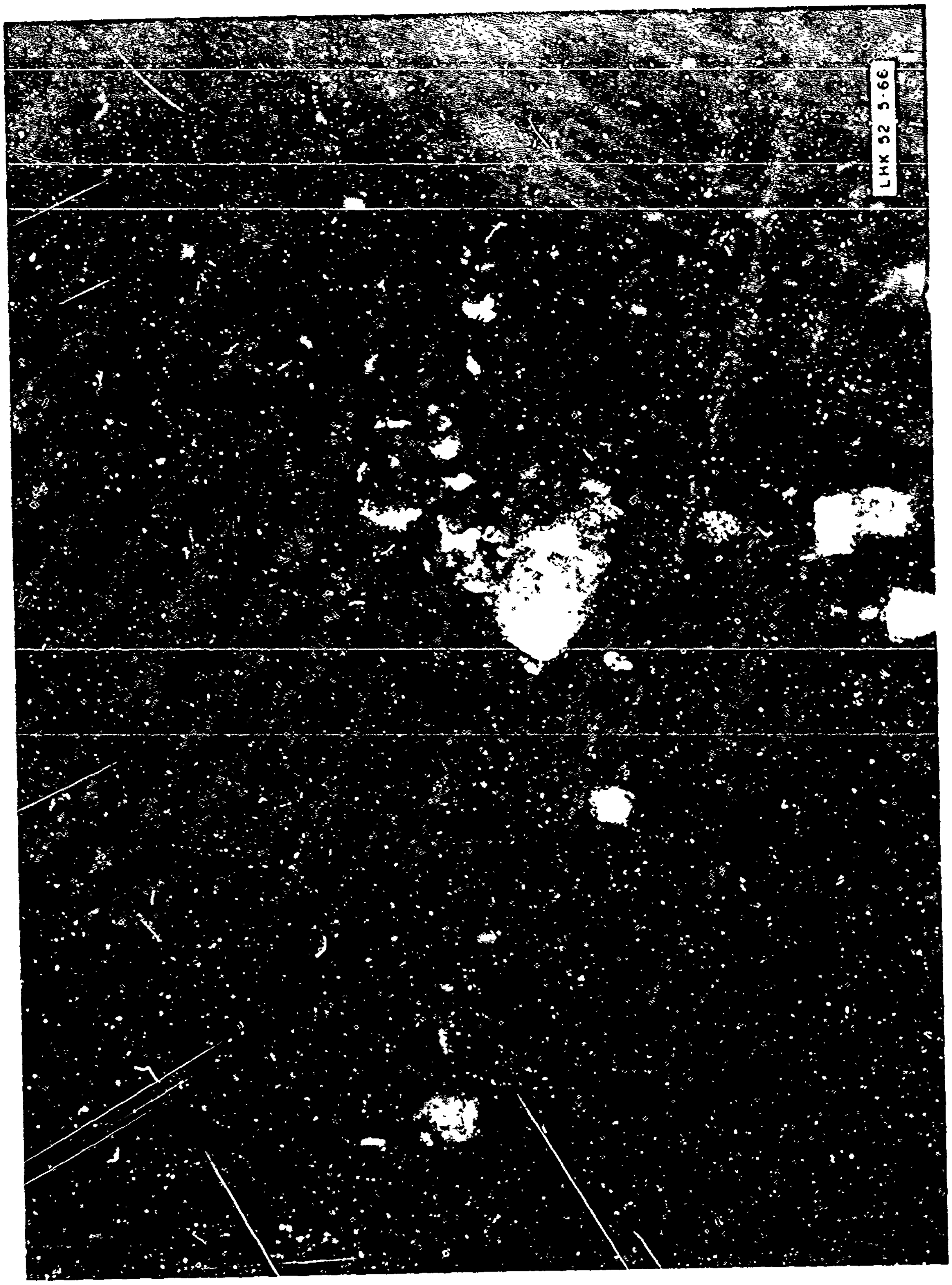

FIGURE 4. Snow Formed by Spraying Cold Water into -50°F Chamber

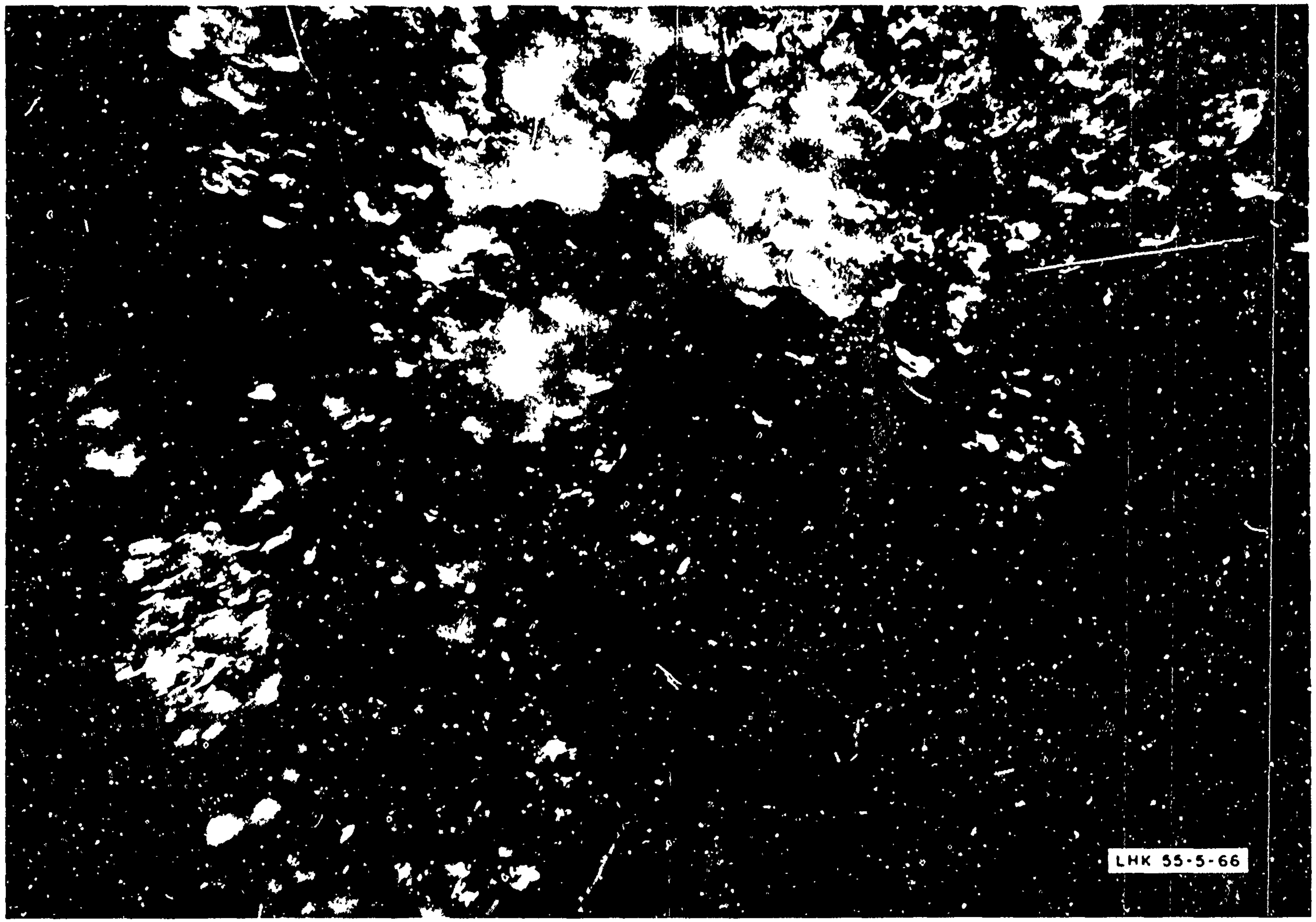

FIGURE 5. Packed Snow (of type shown in Figures 3 and 4) Formed by Spraying Hot Water into -50°F Chamber

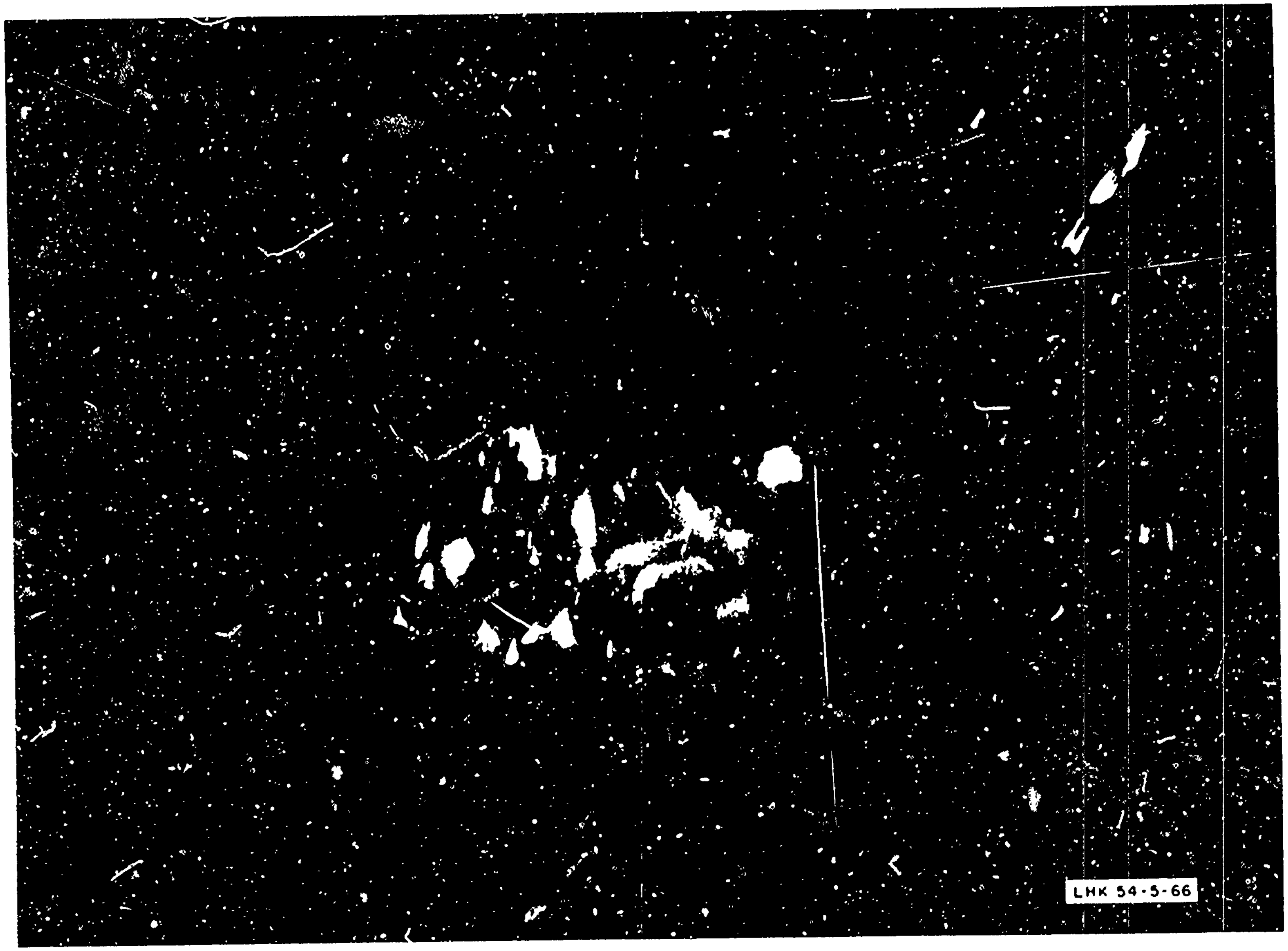

FIGURE 6. Particle of Snow Formed by Spraying Hot Water into -50° F Chamber

In all cases the reflection was about 7.9 percent. The error in measurement is within ±0.5 db for all measurements of attenuation and reflection.

The table shows that the loss in transmitted signal is highest for fine snow with local packed areas and for the large ice crystals. Because the fine loose snow and the packed snow apparently caused less scattering of the radiation, these two types were believed to be more homogeneous than the other samples. The measurements given for the snow sample were consistent from 32 to 39 GHz. The ice sample was measured only at 39 GHz.

CONCLUSIONS

Since the snow samples used in Reference 1 were not photographed, it is not known if the previous samples were identical with those shown here. However, the fact that the results obtained in both cases appear to be comparable indicates that the samples were at least similar. One cannot conclude, however, that the results thus obtained are identical with those that would be obtained from natural snow. Although the densities are very similar to those reported in Reference 3 for natural snow, it is not known whether the transmission characteristics would remain the same for the packed artificial snow spheres and the packed natural snow flakes. It must be concluded, therefore, that these measurements cannot be meaningful until a comparison is made with similar measurements taken on naturally formed snow.

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13. ABSTRACT

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